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A Study in Wedge Waves with Applications in Acoustic Delay- line

Po-Hsien Tung[a], Wen-Chi Wang[a], Che-Hua Yang[a]*

[a]*Graduate Instutute of Mechanical and Electrical Engineering, National Taipei University of Technology, Taipei 106, Taiwan.*

Abstract

The acoustic delay line is usually used to supply protection from dangerous environment, to enhance signal intensity by fit geometry of analyte, or to achieve specific angle/focusing by Snell's law, but rarely to avoid noise from coupling agent and to raise spatial resolution by reducing contact area. This study is focused on wedge waves with applications in delay-line to solve the knot of traditionally transducer measurement. Wedge waves are guided acoustic waves propagating along the tip of a wedge. The advantages of wedge being used in acoustic delay line are wedge waves has large motion amplitude of anti-symmetric flexural (ASF) mode, low energy attenuation and the velocity of ASF more is regular weather frequency varied or not. According the characteristic of wedge wave and vibration direction of particle, the acoustical wedge delay line with high signal-noise-ratio, approximate point-like contact area, without coupling agent and in/out vibration measurement by specific experimental setup is developed.

Keywords: wedge delay-line ; point contact ; in/out-plane signal detection ;

1. Introduction

This study is focused on wedge waves with applications in delay-line. The wedge wave is discovered by Lagasse and coworkers, in the early 1970's through a numerical study, wedge waves are guided acoustic waves that propagate along the tip of a wedge, and the energy is tightly confined near the apex within one wavelength [1]. Like Lamb waves, wedge waves with displacement fields anti-symmetric about the mid-apex plane are called anti-symmetric flexural modes. Fig. 1 shows typical motion pattern of an ASF mode of wedge waves are propagating along the tip of a wedge. Wedge waves has large motion amplitude and low energy attenuation when tip with small

* Corresponding author. Tel.: +886-2-2771-2171#4814;
E-mail address: chyang@ntut.edu.tw

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truncation. Ultrasonic inspection is a type of nondestructive testing commonly used to find defect in materials and to measure the geometry of objects especially thickness. The Early ultrasonic inspection mostly use piezoelectric probe to generate/receive signal to measure thickness or distance. The difficulty of traditional probe measurement is hard to avoid noise from coupling agent and to raise spatial resolution by reducing contact area. Therefore, in 1990 some scholars start against the variety method to reach approximate point contact to generate/receive signal. In 1993, Hsieh and coworkers formed one-point hertz contact between the sphere and the spherical depression in a buffer rod with a transducer to measure material property and surface defect of spherical analyze [2]. In 1996, Degertekin and coworkers Using two quartz buffer rod with cone-shape at one end, and the 5M piezoelectric transducer is connected to quartz to excite/receive signal, the result shows the experimental setup is feasible [3], also the mode selectivity can be achieved by specific experimental setup & different shape of a quarts buffer rod at 1997 [4]. This research of a new signal-detection method based on wedge delay-line is mentioned below.

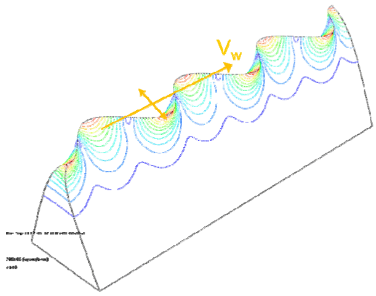

Fig. 1. Wave motion pattern of an ASF mode

2. Methodology

2.1 Acoustic delay line

As shown in Fig.2, the experiment configuration consists of a 5MHz shear wave transducer and a wedge delay-line transducer for ultrasonic excitation and detection. The in/out-plane signal can be excited by rotating the generation source 90° about y axis. In this research, the wedge delay-line transducer is composed of a 2.25MHz shear piezoelectric transducer and an aluminum wedge with apex angle 70°. The truncation of wedge tip is controlled within 12μm to avoid dispersive. Also, the contact force between wedge delay-line and brass block is 5N by using force gage measuring. The signal is detected by oscilloscope with different contact angle (θ) between bisector line of wedge's vertex angle and specimen surface.

2.2 Laser ultrasound technique

As shown in Fig. 3, the experimental configuration consists of a pulsed laser for ultrasonic wave generation and a Acoustic delay line to detect the acoustic waves. The excitation source is a Nd: YAG laser with a power of approximately 100mJ, a wavelength of 532 nm, and a pulse duration of 6.6 ns. A wedge delay line is applied to detect the in/out-plane signal propagating along the specimen. A B-scan scheme is used for the measurement of the dispersion behaviors of wedge waves. During scanning, the optical detector is located at a fixed point, while the generation laser beam is scanned along the specimen including copper plate .A two-dimensional fast Fourier transform, first taken with respect to time and then with respect to the scanned position, is used to obtain the dispersion relation from the B-scan data.

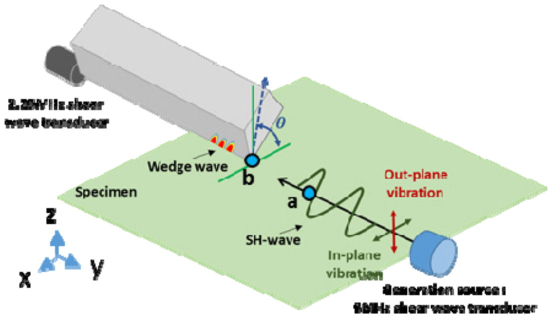

Fig. 2. The sketch is for wedge delay-line transducer

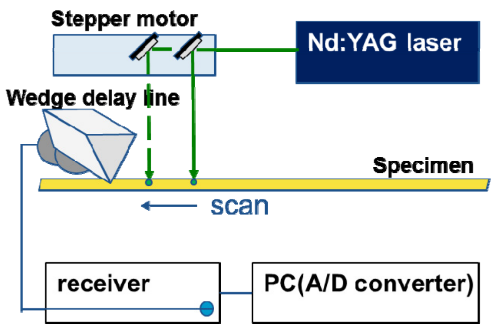

Fig. 3. The sketch is for laser ultrasound technique

3. Results and Discussions

Fig. 4 shows the waveforms measured by wedge delay line transducer at different position A and B. The distance between point A and B is 20mm. The time of fight of A and B are 59.4μs and 69.5μs. Thus, the wave velocity can be calculated is 1981m/s. And the shear wave velocity of brass is 2030m/s. The in-plane shear wave signal can be captured by the equipment setup.

Fig. 5 and Fig. 6 shows the waveforms of the in plane and out-plane signal measurement under contact angle start from 35° to 90° with an interval angle is 5°. As shown in Fig. 7 is the contact angle (θ) corresponding peek of amplitude between in and out plane vibration. The amplitude of in-plane shear wave is found to increase as the contact angle increases. The result shows when contact angle is approaching to 90°, the in-plane shear wave can be observed with better efficiency to detect. The amplitude of out-plane signal is found to increase as the contact angle decreases.

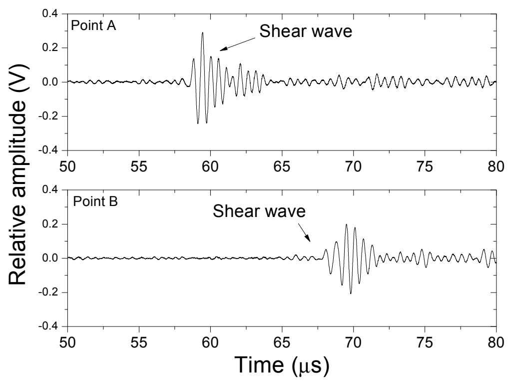

Fig. 4. TOF in different point A & B

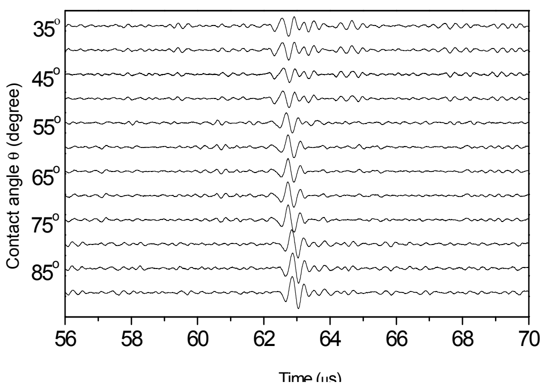

Fig. 5. In-plane signal at varied contact angle θ

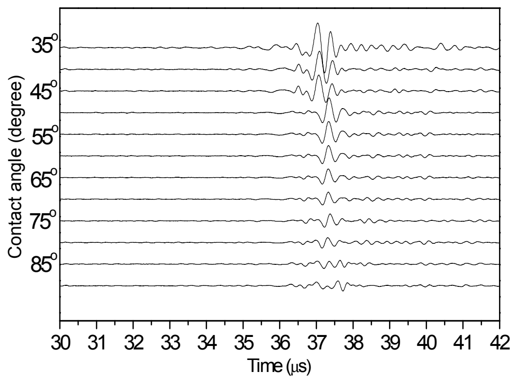

Fig. 6. Out-plane signal at varied contact angle θ

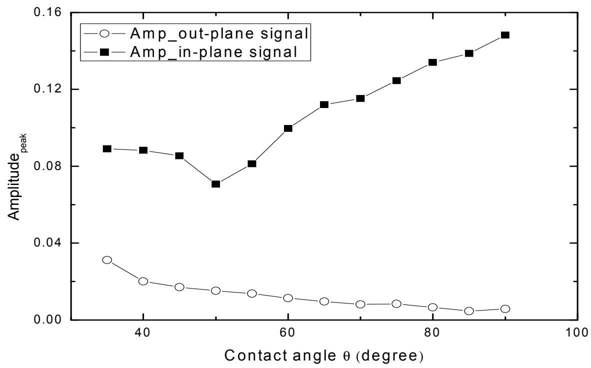

Fig. 7. In/out signal comparison

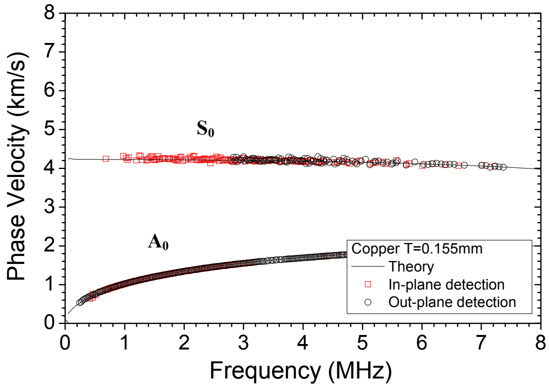

Fig. 8. In/out signal comparison

The result shows when contact angle becomes smaller, the out-plane shear wave can be observed with better efficiency to detect. The feature can be regarded as the wedge delay-line with directivity by specific contact angle.

The Fig. 8 is shown as depression of in/out plane detection is acquired by laser ultrasound technique. The red square/black diamond point is measured by in/out-plane experimental setup separately. The results shown that in/out plane detection can be measured by specific setup. But the red point at S_0 mode of Lamb wave is more observed easily by in-plane experimental setup because the motion of particle is in-plane vibration in S_0 mode at lower frequency range about 1-3MHz. That results shows the directivity can be achieved by wedge acoustic delay line by various contact angle at specific setup.

4. Conclusions

The wedge delay-line transducer are characterized experimentally. While the wedge delay line is in a configuration of contact angle near 90°, the detection for the in-plane shear wave is found to be very efficient. Advantages of wedge delay-line transducer include point-wise contact area, no coupling agent needed and directivity by specific contact angle. This research aims at the development of a new signal-detection method based on wedge delay-line. The acoustic wedge delay line can be a new candidate for raising imagine resolution or detecting complicated geometry without coupler /surface-clearing even at fluid-loaded environment measurement.

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